EFFECTS OF COGNITIVE COMPLEXITY IN AGENT SIMULATION: FUZZY RULES AND AN IMPLEMENTATION

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ABSTRACT

This article is a sequel to a series of articles where the authors (1) gleaned the personality knowledge based on the five personality traits and six facets for each trait to form a basis for fuzzy agents with personality; (2) promoted the concept of dynamic personality for fuzzy agents; and (3) pointed out the pivotal relationships of personality trait openness with both problem solving ability and cognitive complexity. The last characteristic of openness leads to its impact to dynamic modification of problem solving ability. In this article, an implementation of a fuzzy agent with personality is realized in Java environment to show personality descriptors, personality factors, personality style, and problem solving success consequently. Furthermore, a prototype system is presented to update personality facets and respective personality trait openness which can affect problem solving ability.

1. INTRODUCTION

Agents with personality are software agents which can represent human personality traits. They can represent human personality at coarse grain or fine grain levels. *At coarse grain level*, they can represent some or all relevant characteristics such as openness, conscientiousness, extraversion, agreeableness, and negative emotions in line with the five-factor personality theories to model human behavior. *At fine grain level*, the facets of each personality trait are also represented. Several studies exist on agents with personality. For example, Rizzo et al. (1997) describe work aimed at realizing believable agents that perform helping behaviors influenced by their own personalities. Schmidt (2002) presents the framework of the PECS (Physic, Emotion, Cognition, and Social Status) architecture where a system-theoretical methodology is used for specifying agents' personality traits. Allbeck and Badler (2002) present work toward representing agent behaviors modified by personality and emotion. To this end, they describe a parameterized action representation (PAR) for building future behaviors into autonomous agents and controlling the animation parameters that portray personality, mood, and affect in an embodied agents. Egges et al. (2003) describe a generic model for personality, mood and emotion simulation for conversational virtual humans. Rousseau and Hayes-Roth (1997) report work on actors with flexible personalities.

At fine grain level, a realistic refinement is *dynamic personality* to take into account the variability of personality traits based on the changes in corresponding personality facets. When at least any one of the 30 facets changes its value, the personality may be affected and *personality update* can take place, i.e., the personality should be re-evaluated with the implications of the corresponding personality trait. Personality update corresponds to a discontinuity and model update. For a generalized view and implications of discontinuity and model update see Ören (1991). Series of personality updates would also allow realization of evolutionary models of personality.

A systematic presentation of human personality knowledge, including dynamic personality processable in fuzzy logic for human behavior simulation is given by Ören and Ghasem-Aghaee, (Ören and Ghasem-Aghaee 2003; Ghasem-Aghaee and Ören, 2003). *Fuzzy agents* are agents that can perform qualitative uncertainty reasoning with *incomplete and fuzzy knowledge* in some environment that contains linguistic variables. *(Fuzzy) agents with dynamic personality* are (fuzzy) agents with personality where personality knowledge is updateable. The effect of cognitive complexity in decision making within complex situations has been known since a long time (Athey 1976; Ören 1978) and the relationship of cognitive complexity and one of the personality traits, i.e., openness is also well accepted (McCrae, 2000). These facts lead to tying cognitive complexity with personality update in fuzzy agents with dynamic personality (Ghasem-Aghaee and Ören, 2004; Seck et al., 2005). The plan of organization for the rest of the paper is as follows: personality knowledge and dynamic

personality are presented in section 2. Cognitive complexity is given in section 3. Some fuzzy rules to show personality descriptors, relationship of cognitive complexity and problem solving are explored in section 4. Finally, the class diagram and the outputs of the program that is implemented in Java environment are presented in section 5.

2. PERSONALITY KNOWLEDGE AND DYNAMIC PERSONALITY

The term personality refers to the sets of predictable behaviors by which people are recognized and identified. These sets of behaviors go by the name of personality traits or factors. A contemporary view of traits considers in five dimensions, i.e., five-factor model of personality: (*Openness, Conscientiousness, Extraversion, Agreeableness, and Negative emotions*); each trait has six *facets* (Costa and McCrae 1992; Howard, 2000, p. 433; Acton 2001; Howard and Howard, 2001a, b; Ören and Ghasem-Aghaee, 2003). Cognitive complexity is related with openness. As shown in Table 1, depending the three levels (i.e. low, medium, or high) of the openness, three types of personalities are identified as preserver, moderate, and explorer. Each facet has a weight factor. In the determination of the overall value of a trait, the weighted value of each facet is computed by multiplying its measured value by the weight factor. The dominant facet determines the value of the trait. There is a need to find a way to represent the continuum of openness which can allow a person to be for example, 0.30 preserver and 0.70 explorer.

Table 1. Personality descriptors based on the levels [or values] of the six facets of **openness** and corresponding personality types and characteristics

Facets of **openness**	Levels		
	low	medium	high
Fantasy	focuses on here and now	occasionally imaginative	Imaginative, daydreams
Aesthetics	uninterested in art	moderate interest in art	appreciates art and beauty
Feelings	ignores and discounts feelings	accepts feelings	values all emotions
Actions	prefers the familiar	a mixture of preference of the familiar and the new	prefers variety, tries new things
Ideas	narrower intellectual focus	moderate curiosity	broad intellectual curiosity
Values	Dogmatic, conservative	moderate	open to new values open to reexamining values
Personality type	**Preserver**	**Moderate**	**Explorer**

3. COGNITIVE COMPLEXITY

In most decision making processes, ability of coping with complexity is a fundamental issue and influences the quality of the decisions. Based on Athey's work (Athey 1976), Ören (1978) elaborated on the importance of increasing cognitive complexity of an individual to increase his/her effectiveness in coping with complex situations. In two recent articles the effect of cognitive complexity on problem solving ability were revised (Ghasem-Aghaee and Ören, 2004; Seck et al., 2005). Here, only state the salient features are revised. For a low situational complexity, an individual may need to have low level of information processing to cope with the situation. If the situational complexity increases, his/her information processing level may also increase. However, for each individual there is a critical point beyond which the level of processed information hence the individual's information processing effectiveness is decreased. After the critical point, an increase in the situational complexity may worsen the individual's ability to cope with complexity, by causing a decrease in his/her level of information processing.

The comparison of the information processing curves of two types of individuals reveal the following two facts: (1) The critical point of high cognitive complexity individual is higher than the critical point of low cognitive complexity individual. (2) For a given situational complexity, the level of information processed by a high cognitive complexity individual is greater than the information processed by low cognitive complexity individual.

Additional characteristics of high and low cognitive complexity individuals (with relevance to managers) are given by Streufert and Swezey (1986). As stated by Streufert and Swezey, (1986), "persons who are high in cognitive complexity are able to analyze (i.e., differentiate) a situation into many constituent elements, and then explore connections and potential relationships among the elements. … Complexity theory assumes that the more an event can be differentiated and the parts considered in novel relationships, the more refined the

response and successful the solution. … high complexity people are very flexible in creating new distinctions in new situations." It is indicated in Chapter 12 of the handbook of emotional intelligence that "openness has also been associated with other cognitive or quasi-cognitive variables, including moral reasoning, cognitive complexity and wisdom" (McCrae, 2000).

The relationship of cognitive complexity and openness as a personality trait inspires applicability of personality update concept of dynamic personality to cognitive complexity. The personality facets which affect openness are: fantasy, aesthetics, feelings, ideas, and values. The dominant facet, i.e., the one having the largest weighted value determines openness. Any value change in any of the personality facets affecting openness may induce a personality update and change in the value of openness to affect the cognitive complexity of the individual.

4. FUZZY RULES

The following fuzzy rules, in Table 2, show the relationship of cognitive complexity and problem solving. In these fuzzy rules, the degree of problem solving success is determined by the value of problem complexity (defined by the user) and the value of cognitive complexity (defined by the value of openness). We have implemented these fuzzy rules, such that, after fuzzy inferencing and defuzzification, the degree of the agent problem solving success is determined. Due to space limitation, we report a few sample fuzzy rules in Table 2. Some fuzzy rules to represent *personality descriptors* based on the values of the personality facets of openness are given in Table 3. To save space only some sample rules are given. O_fantasy denotes the characteristic (descriptor) of the fantasy facet of the Openness trait of personality.

A more general way to determine the value of a trait is to consider the degree (value) of a trait, which is the degree (value) of the current dominant facet.

The degree of a facet is its weighted value (equal to the product of its measured value by its weight factor as determined from factor analysis). This way of determination also covers the special cases where all facets have same values. El-Nasr and Skubic [1998] also propose that the agent acts on the emotion with the highest intensity and Gadanho and Hallam [2000] use the current dominant emotion.

Table 2.Some fuzzy rules to represent relationship of cognitive complexity and problem solving.

IF	Cognitive Complexity	is low
AND	Problem Complexity	is low
THEN	Problem solving success degree	is high.
IF	Cognitive Complexity	is low
AND	Problem Complexity	is medium
THEN	Problem solving success degree	is medium
IF	Cognitive Complexity	is low
AND	Problem Complexity	is high
THEN	Problem solving success degree	is low
IF	Cognitive Complexity	is high
AND	Problem Complexity	is low
THEN	Problem solving success degree	is very high
IF	Cognitive Complexity	is high
AND	Problem Complexity	is medium
THEN	Problem solving success degree	is high
IF	Cognitive Complexity	is high
AND	Problem Complexity	is high
THEN	Problem solving success degree	is medium
IF	Cognitive Complexity	is low
AND	Problem Complexity	is very high
THEN	Problem solving success degree	is low

Table 3. Some fuzzy rules to represent *personality descriptors* based on the values of the personality facets of openness

IF	fantasy	is high.
THEN	O_fantasy	is imaginative
IF	aesthetics	is low
THEN	O_aesthetics	is uninterested in art
IF	aesthetics	is high.
THEN	O_aesthetics	is appreciates art and beauty
IF	feelings	is high.
THEN	O_feelings	is values all emotions
IF	feelings	is low
THEN	O_feelings	is ignores and discounts feelings
IF	actions	is high
THEN	O_actions	is prefers variety
IF	ideas	is low
THEN	O_ideas	is narrower intellectual focus
IF	values	is low.
THEN	O_values	is dogmatic, conservative
IF	values	is high.
THEN	ideas	is open to new values, open to reexamining values

As an example for the determination of the value of a trait from the dominant values of its facets, let's consider the weighted values of the facets as follows:

Low<45, 45<=medium<=55, high>=55). Then the fuzzy rule follows:

			degree
IF	fantasy	is low	20
OR	aesthetics	is medium	50
OR	feeling	is high	80
OR	actions	is low	20
OR	idea	is high	90
OR	values	is high	85
THEN	openness	is high	90

5. AN IMPLEMENTATION

Figure 1 shows the class diagram of the program. Each class contains the main attributes and the methods (class name at the top, attributes at the middle, and dynamic personality. Each facet has a weight factor. In methods at the bottom). The software is implemented in Java environment and contains an agent with the determination of the overall value of a trait, the weighted value of each facet is computed by multiplying its measured value by the weight factor. The dominant facet determines the value of the trait. The outputs in Figures 2-5 show personality descriptors, personality factors, personality style, and problem solving success consequently.

6. CONCLUSIONS

Personality traits are stable; however, they can be modified by proper training (Howard 2000). Model update is a promising modeling methodology (Yilmaz and Ören, 2004). Dynamic personality is yet another aspect of model update and would allow, as clarified in another article (Ören and Ghasem-Aghaee, 2003), reflections of the changes of personality facets in the corresponding personality traits with relevant implication on the behavior of agents. Representation of dynamic personality in fuzzy agents was presented by Ghasem-Aghaee and Ören (2003). In this article, we pointed out to the fact that openness, as a personality trait, is related with cognitive complexity and hence updates on openness may have implications on cognitive complexity and to the decision making ability of the agents in problem solving. An implementation of a fuzzy agent is reported to represent the effect of modifications of facets of openness to the ability to cope complexity. Also, the outputs of the prototype show personality descriptors, personality factors and personality style. Our current work on the relationship of personality and emotions on decision making will be presented in a forthcoming article.

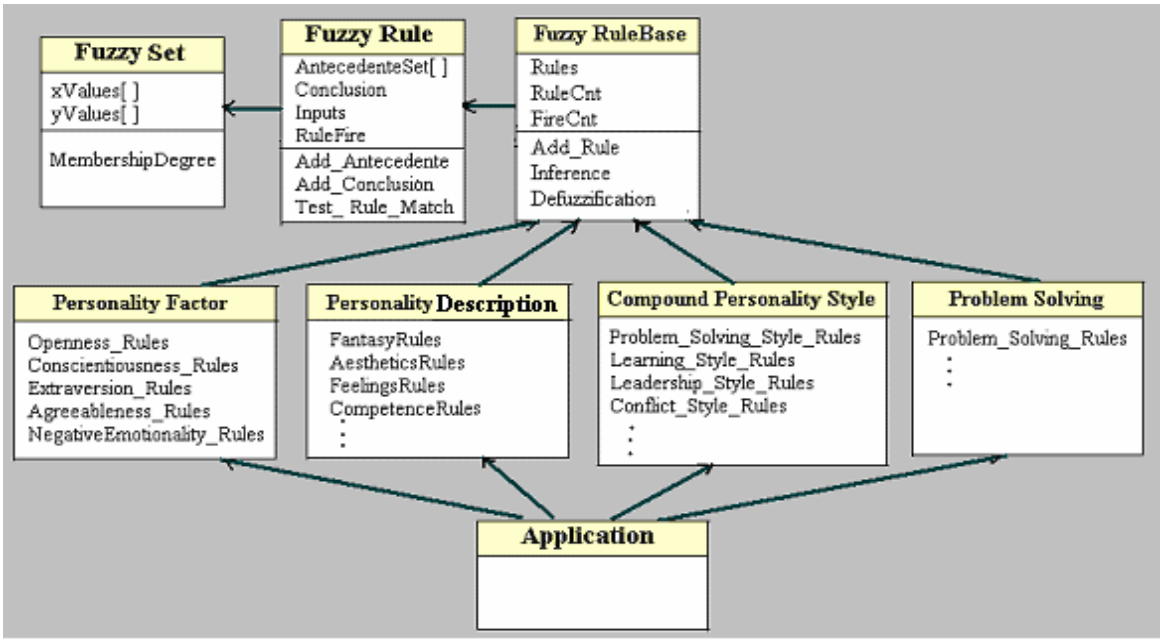

Figure 1. Class diagram of the Program

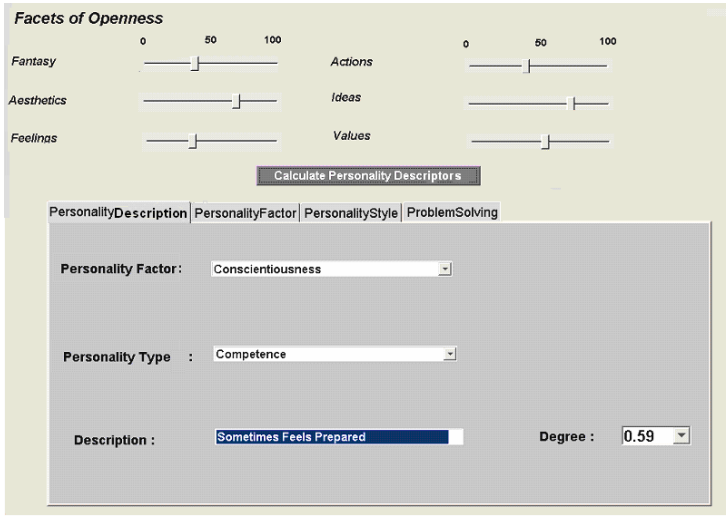

Figure 2. Personality Descriptors

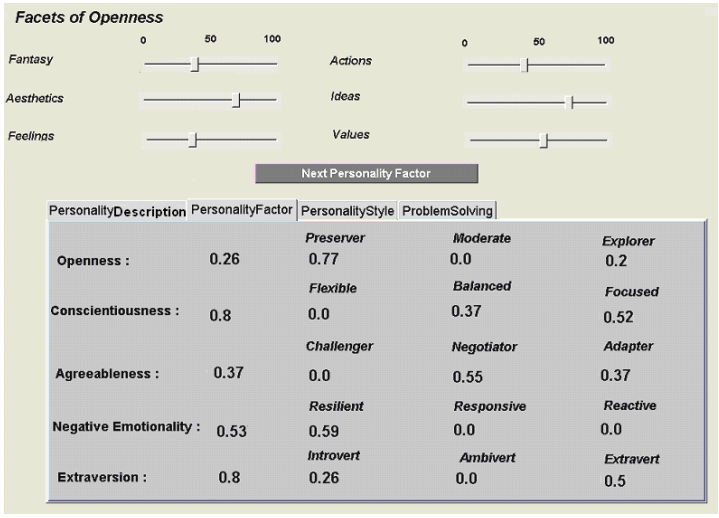

Figure 3. Personality Factors

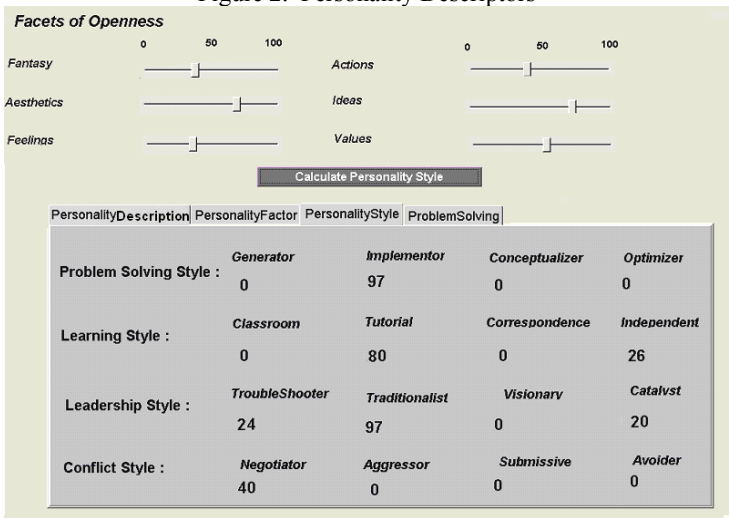

Figure 4. Personality Style

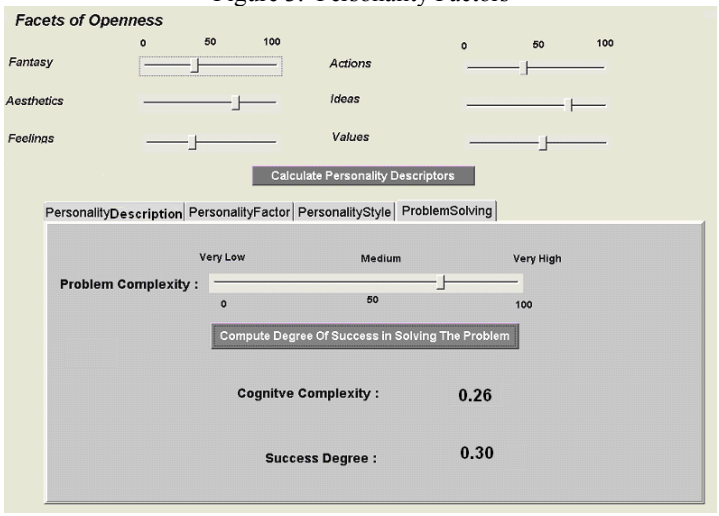

Figure 5. Problem Solving Success

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